An Introduction to a Transnational Volunteer Notification System Providing Cardiopulmonary Resuscitation for Victims Suffering a Sudden Cardiac Arrest

Jesko Elsner, Marie-Thérèse Schneiders, Max Haberstroh, Daniel Schilberg and Sabina Jeschke
Institute of Information Management in Mechanical Engineering
IMA/ZLW & IfU - RWTH Aachen University
Dennewartstr. 27, 52068 Aachen, Germany
{ Jesko.Elsner, Marie.Schneiders, Max.Haberstroh, Daniel.Schilberg, Sabina.Jeschke }
@ima-zlw-ifu.rwth-aachen.de

Abstract—**While it is always desirable in an emergency to get treatment as soon as possible, there are emergencies that need immediate treatment. In case of Sudden Cardiac Arrest an untreated time interval of only a few minutes usually means the victims' death. Given the delay between an incoming emergency call and the arrival of the emergency medical services at the scene, it is necessary to find an alternative way to provide immediate first aid treatment. One approach for this is the implementation of a Volunteer Notification System – involving laypersons and medically trained volunteers into the emergency medical service, by notifying those potential helpers who can arrive at the scene fast enough to provide the urgently needed measures.**

Keywords—Volunteer Notification System; First Responder; Emergency Medical Services; Sudden Cardiac Arrest; Cardiopulmonary Resuscitation; Telemedicine

I. Introduction

Due to the way today's professional emergency medical services (EMS) are organized, victims in need of urgent medical care are facing a lethal problem. Depending on the type of emergency, the time interval between the incoming emergency call and the arrival of the professional helpers at the scene is simply too long. In Bavaria (Germany) for example, a region with good infrastructure and an advanced medical system, reoccurring studies are made every four years, in order to analyze the effective time interval local EMS need until arriving at the place of incident. The institute for emergency medicine in Munich (INM) states in a recent study that professional EMS in the area of Bavaria require approximately 9 minutes until arriving on scene [2]. Furthermore, the study underlines an ongoing increase in this deficit due to a diversity of reasons. The severity of the time deficit generally correlates with the infrastructure a country can provide, resulting in intensification for less advanced countries and regions. While most emergencies do not involve an immediate life danger for the victim, in case of a Sudden Cardiac Arrest (SCA) the first minutes are of utter importance. Jan Bahr states that as little as three minutes is most likely enough for victims of SCA to suffer permanent brain damage and Karin Grassl describes within her dissertation that the survival rate after five minutes without treatment is practically zero [6, 7]. Victims suffering SCA are in need of urgent medical care that professional EMS alone cannot always sufficiently provide.

A. Structure

The first chapter of this paper describes the medical emergency of a Sudden Cardiac Arrest (SCA) and introduces the basic concept of a Volunteer Notification System (VNS). Starting by identifying and discussing comparable systems, the second chapter focuses on analyzing the technological state-of-the-art of mobile devices and data communication concepts; herby determining the possibilities and restrictions for a VNS approach. The third chapter introduces the current project "EMuRgency". As one focus of the project is the actual implementation of a new VNS, the core components and the corresponding architectural details are being discussed. The fourth and thereby last chapter of this paper introduces the conclusion and shortly discusses a potential generic approach and some optional features.

B. Sudden Cardiac Arrest

The human heart has an electrical conduction system that controls the rate and rhythm of the heartbeat. Problems with this electrical system can cause irregular heartbeats called arrhythmias which can lead to Sudden Cardiac Arrest (SCA) - a condition in which the heart suddenly and unexpectedly stops beating. The hereby resulting loss of blood flow prevents the brain and any other vital organ from getting oxygen. Without immediate treatment, the victim dies within minutes. It's a common misconception that SCA is the same as a heart attack, while in reality, they are quite different. SCA is an "electrical problem" that prevents the heart in its whole from functioning, whereas a heart attack occurs when part of the heart's blood supply is reduced or blocked causing the heart muscle to become injured or die. [1]

C. The basic concept of a Volunteer Notification System

One possible solution for offering faster response treatment is the concept of involving volunteers into EMS by implementing a Volunteer Notification System (VNS). A VNS may be defined as an IT system with the following core functionality: by tracking the location of all registered users, the system will be able to notify exactly those potential

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helpers who are, at the time of the incoming emergency call, geographically close to the place of incident.

This concept of a VNS does not interfere with the local corresponding emergency standard procedures, but can rather be described as an optional add-on to existing EMS; the responsible dispatcher takes the decision if to involve this optional feature. It is important to understand that the potential volunteers are not a replacement for emergency physicians or any professional helper that has been alarmed, but their main purpose is to arrive at the scene fast enough to start Cardiopulmonary Resuscitation (CPR). While there is no exact definition or specification of a VNS yet, it is part of this paper to discuss a potential architecture and distinguish between the core and the optional functionalities of such a system. The technical implementation of an integrated VNS is the focus of the European research project "EMuRgency" which will be described in the chapter three.

II. STATE OF THE ART

A. Existing systems with similar functionality

While a diversity of local approaches to implement notification systems exists already, those approaches generally do not have an academic motivation or background. Therefore, publications on the aspect are still rare and the corresponding projects are opening neither their expertise nor the source codes to the public. The only publically available resources are the corresponding application download, some basic usage documentation and a reference document for the Advanced Programming Interface (API) – which merely offers functionality for providing the systems with data [13].

Based on reviews and the appearance in media all over the USA, the PulsePoint Foundation for example offers one of the most advanced software implementations in the field of emergency notifications at the moment [15]. Formerly known as the "Fire Department App" and developed for iOS only, the new version is available under the name "PulsePoint" for Android and iOS [14, 13]. Even though this application is surely great for offering everyday people a possibility to save lives, based on the available documentation, it is a US-only solution without open interfaces. From an academic point of view, it is regrettable that the achieved competences are not shared, which in combination with non-open source codes makes it is nearly impossible to use the project as a base for a scientific work. Furthermore, the implementation approach is rather static, only allowing two types of mobile devices (Android and iOS) as recipients and no other but US specific regulations, legal circumstances and network characteristics are supported. There are a few smaller projects with less impact and publicity, but the problems stay the same.

Beside the difficulties to communicate and rely on more or less closed projects for information flow and depend on their goodwill, the available solutions are implemented as local solutions that cannot easily be adapted to other countries, regions or new legal environments. Fundamental changes are needed in order to use these systems with other than the original parameters and the underlying model itself does not provide a reasonable extension of functionality without making changes to the actual source code itself.

In summary, the currently available systems lack essential interfaces, public tools for gathering and extracting information, an efficient communication flow and basic concepts for extensibility; therefore it seems inevitable to provide a new approach to the topic rather than upgrading an existing one.

B. Mobile technologies

Advances in mobile technologies and the continuous growing popularity for portable digital devices with internet access in nowadays society offer a great starting point for VNS. Without supplying any special devices, a VNS is able to communicate with a huge variety of volunteers by simple using the existing hardware and infrastructure that people own and use anyway. Modern smartphones for example offer a diversity of features that may be used to aid potential helpers in their mission to arrive on scene as early as possible. Some notable built-in features are real time Internet connections, notification options with vibration and sound, photo and video modes, a variety of sensors to enable situation based functionality like a compass, and the fact that actually any modern mobile device is running an operation system (OS) that supports programmatic solutions for individual software.

Based on the basic definition of a VNS, the core functionality of any VNS is the effective localization of the volunteers. The actual localization of mobile devices within a network is a complex matter, while the reliability of the results generally depends on the corresponding network provider and its infrastructure [12]. Different companies and research groups are working on this topic, offering a variety of Advanced Programming Interfaces (API's) with base functionality to access localization data for different types of devices. One of the most advanced examples is Android's Location API, which is part of the Android software platform, developed by Google in conjunction with the Open Handset Alliance (OHA) [11].

The OHA is a consortium of 86 companies, working on developing and advancing open standards for mobile devices. The consortium, led by Google, includes some of the biggest mobile operators like Telekom and Vodafone, as well as some important manufacturers of mobile devices like Samsung and HTC. As an open-source project, the Android source code is publicly available and can be accessed freely; this reflects in a high user acceptance and fast development progress due to contributions from the open source community. The comScore Incorporation recently published a report on the mobile subscriber market for the second quarter of 2012, by which Android is holding an average of more than 60% market share within the biggest countries of Europe [4]. In a press release from august 2012, the International Data Corporation (IDC) identifies the Android market share at even 68% worldwide and underlines that these numbers are increasing [5]. Both studies are based on device sales in the corresponding regions and therefore reflect the general tendency within the segment of smartphones and other mobile devices with internet access.

Even though restricting the notification recipients to exclusively smartphones and similar devices running Android is questionable, it seems to be a reasonable decision for rapid prototype development in order to provide an early running system as soon as possible. It must clearly be stated that a limitation of this kind can only be temporary and that a final model of a state-of-the-art VNS has to provide a generic communication approach in order to support a broad variety of different devices. A more detailed discussion on the topic of a possible generic approach will follow in the upcoming sections of this paper.

C. HTML – the language of the World Wide Web

The Hypertext Markup Language (HTML) defines the core language of the World Wide Web (WWW). With the HTML 5 specification becoming the new standard for web interactivity, a lot of features are accessible for programmers to enable client and server technologies to communicate with each other. While a detailed discussion on server push technologies and HTTP requests would clearly exceed the context of this paper, it is important to note that the HTML 5 specification includes full support for so-called WebSockets. WebSockets specify an API as well as a protocol, while the protocol defines the HTTP handshake behavior to switch from an existing HTTP connection to a lower level connection; a so-called WebSocket connection. While a common approach over the last years was to simulate a server push channel over HTTP, a WebSocket connection enables bidirectional communication natively. Referring to the possibilities for the client/server communication within a VNS, the WebSocket approach offers a clean and simple communication concept and enables a generic implementation for any devices complying with the HTML 5 specification. [10]

III. THE EMURGENCY PROJECT

The European research project "EMuRgency" has been started in September 2011. Research facilities from Germany, the Netherlands and Belgium are working together on modeling and implementing an integrated Volunteer Notification System (VNS) to gap the time between an incoming emergency call and the arrival of professional helpers at the scene. The name of the project is a composition of the two words "emergency" and "urgent" and refers to urgent help that is needed in case of SCA. The three upper case letters "EMR" identify the regional base of the project; the "Euregio Maas-Rhein" (Eng. "Meuse-Rhine Euroregion").

A. Definition of the term "volunteers" within a VNS

Before describing the system, its components and the technical details, it needs to be clarified which group of people can actually participate as volunteers within a VNS. A volunteer can be anyone with basic skills in first aid and CPR (Cardiopulmonary Resuscitation) who is willing to help in case of an emergency. It is important to differentiate this definition from the term "first responder" which was defined by US National Highway Transportation Safety Administration as "the first medically trained responder who arrives on scene of an emergency" [3]. While the definition of a first responder includes groups like police officers, firefighters and EMS, it does not include laypersons since those generally do not have medical training. Still, laypersons might be able to provide the needed measures in order to help victims of SCA and thus should be included as potential helpers within a VNS. Within the EMuRgency project, the term "volunteer" is referring to any potential helper, medically trained or not, willing to aid other people in an ongoing emergency.

B. Integration between VNS and professional EMS

Whenever an incident is reported to an emergency dispatch center that might involve SCA, the dispatchers will do what they normally do: send professional help - but optionally also invoke the VNS. It is important to stress that the VNS, at this time of development and based on the way EMS is organized today, is a merely optional feature. This means that the responsible dispatcher may or may not involve the VNS, depending on their analysis of the case and personal motivation. In order for the optional integration to be achieved, the VNS has to provide a user-interface where the dispatcher can initiate a case by forwarding its exact location and some optional information to the system. During SCA, time is of utter importance, so this user-interface has to be as simple and efficient as possible.

Recent interviews were made within the project in order to determine the acceptance and motivation of the dispatchers to integrate a VNS within the general workflow; Even though all the interviewed dispatchers agreed on a potential benefit, it became rather clear that the general acceptance of new systems seems to directly correlate with the extra work that is involved in order to use it. Taking into account the discussed optionality and the still early stage of development within the project, a manual integration will be the starting point towards involving the VNS within the professional EMS workflow. The implementation of an integrated system that gets activated fully automated during a reported emergency is surely desirable, but requires detailed collaboration with the corresponding software providers. Details on this topic are will be addressed in future papers.

C. How to determine the relevant volunteers in an ongoing emergency

As soon as the system receives information on a new emergency, no matter if automated or manually initialized from the dispatcher, the VNS will determine possible volunteers in the closer vicinity of the incident and immediately inform those in walking distance of the ongoing emergency. In order for this to be possible with minimum time effort, the system needs to be "aware" of all potential volunteer locations at the time of the incoming emergency call. This awareness can be achieved by making all connected clients publish their locations to the server in pre-determined time intervals, rather than forcing the server to request all client locations at once not until they are actually needed.

Before notifying any potential helper, a reasonable maximum distance between a volunteer and the incident has to be determined. Only volunteers located within the maximum distance will be considered potential helpers in an on-going notification. The distance that an individual person can travel within - let’s say - five minutes depends on many different parameters. An older person, for example, might walk slower than a younger person, while some people are simply in a better shape than others, no matter the age. Due to a great variety of individual parameters influencing a proper notification radius, a suitable solution to begin with, is creating a personalized profile setting; giving any registered volunteer the option to define an individual notification distance by configuring the appropriate parameter in their user profile. To maintain a realistic range, the maximum distance a user can set is limited to 1 km at the moment. Within the project, this functionality is implemented by using a public accessible browser based Web Application; accessing the corresponding URL, new users can register and/or edit their profile settings online. From the technical point of view, this Web Application is a frontend for accessing database functionality on the server.

D. Webservices

In order to enable external sources, for example mobile clients or applications from project partners, to access specific functions on the server, a different approach is needed. Specific APIs provide mobile clients the necessary functions in order to communicate with the VNS without having to access a web browser. The same approach can offer project partners an interface for integrating alternative ways of volunteer registration into the main system. Commonly used solutions for offering a limited scope of functionality to external clients are are so called Webservices or more specific, REST based Web APIs [9]. By implementing Webservices, a predefined set of functions will become globally available; different devices will be able to communicate with each other over a given network infrastructure; like for example, the World Wide Web.

E. The messaging architecture

At the time of writing, a running prototype of the VNS is available already. The upcoming section will introduce the used messaging architecture and describe the essential components implemented for the different types of communication.

As long as a client is not involved in an ongoing case, the main communication that occurs between the mobile clients and the server is a client-to-server location publishing that automatically gets invoked in a predefined time interval. While a simple implementation approach for this is a common HTTP POST method, the push communication used to send data from the server to a specific client is an entirely different matter. The World Wide Web (WWW) was originally not intended to support bidirectional communication and therefore does not include the corresponding specifications or protocols. With HTML 5 introducing the WebSocket JavaScript interface, a native solution for bidirectional communication is available. Once a WebSocket connection has been established between client and server, instant data communication becomes possible between both sides without explicitly having to deal with technical differences. Based on this kind of real time connectivity, a variety of different features can be implemented, including chat channels for notified helpers and live camera streaming from the place of incident. A short discussion on optional features in general will follow in the outlook section of this paper.

Even though real time connectivity with WebSockets is a promising approach for implementing specific functionalities, having hundreds or thousands of idle clients permanently connected to the system is definitely not a suitable solution. An increased energy consumption of the mobile clients and a possible server overload due to an increasing number of connected clients are the two main reasons for this. Besides, when not involved in an ongoing emergency, only two types of messages are actually exchanged: firstly the location updates that occur every couple of minutes and are sent from client to server, and secondly the event data that is sent from server to client in order to update the main information view and to display upcoming events, training-courses etc. Since HTTP requests generally include a response-content, the message flow for general information and event data has been implemented as a response to an occurred location update and thus does neither need any special connectivity nor an additional request. It is common practice to restrict HTTP get requests to merely read-only operations and implement any request that modifies data on the server as HTTP post. The main difference between these two types of requests is that within an HTTP get request, the key/value pairs are specified in the URL, whereas in an HTTP post request, the key/value pairs are sent after the headers, as part of the request itself.

Analyzing the base functionalities, there is one type of message that cannot wait for the next “location publish” in order to be sent as a reply from server to client, but instead needs to be send instantly; a new case notification message. This message initiates a new case on the server and alarms any potential helper in walking distance to the emergency; the message needs to arrive on the client with the smallest delay possible. In order to push messages from a server to a mobile client, different cloud messaging solutions are available but generally represent very individual solutions that only work for specific devices or operation systems. The Google Cloud Messaging for Android (GCM) for example is a specific solution to send data from a server to an Android application.

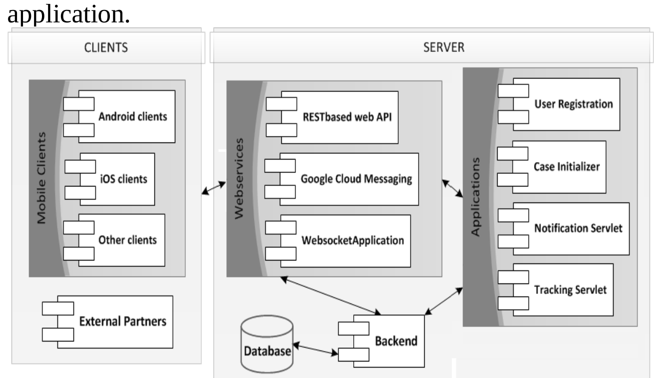

Figure 1: Core components of the EMuRgency VNS

To summarize the messaging architecture at this point of development, HTTP post requests are implemented for client-to-server location updates; the response content of the is then processed in order to send event data from the server back to the client; new cases are initialized by using device specific APIs in order to push notification messages from the server to the mobile clients; and a real time WebSocket communication gets initialized on a new case event for all notified volunteers.

F. *An integrated VNS platform*

As a scientific project with partners from both technical and sociological research fields, the project is focusing on many more aspects than a simple technical approach for a notification system. Users of the system will be informed on ongoing events or urgent news and since a common interest level of registered people can be implied, communication channels for exchanging know-how and general information are being implemented. A real-time information flow regarding the aspects of first aid and CPR is extending the core notification functionality. While also developing concepts on raising public awareness on SCA, educational content is displayed at frequently used public places; and if in digital form, the streamed content will be enriched or synchronized with data from the VNS. Furthermore, in order to receive substantial scientific results and to determine the potential benefit of a VNS, corresponding reporting and analyzing features are being designed. Open interfaces will supply options for non-project members to change or extend functionalities. Although details on the generic approach and corresponding concepts for an open architecture are not yet fully developed, an integrated VNS platform will combine the different research topics with the diversity of requirements that are to fulfill.

G. *Regional differences for involving laypersons into professional EMS*

It is important to understand the actual role of an occurring registration and the resulting implications on the system and the user. A newly registered user for example, obviously wants to help, but comparing different countries, potential differences between the way that laypersons are legally allowed to be integrated into EMS, must be considered [16]. Some regions for example might not allow the integration of laypersons in EMS at all; and is a layperson with first aid skills but without corresponding certificates still a layperson? While those questions will not be discussed further within this paper, expert legal advices for different countries are contracted, in order to validate this matter. The direct implication concerning the VNS is that a new user by default will be “unconfirmed” and will not be considered a potential volunteer until “confirmed”; the confirmation process on the other hand is implemented in a separate administrative component, whereas the final details of this component are not yet fully worked out.

H. *An overview of the primary components within a VNS*

Within the past sections of this paper, the core components of a VNS have been shortly introduced in their corresponding context. Fig. 1 shows an overview of these components while the following paragraph will give some additional information on how they have been implemented.

1) User Registration: Implemented as web application, this component offers base functionality for new users to register to the system; existing profiles can be edited and specific settings can be configured by the user – one example for a user specific setting is the notification radius.

2) Case Initializer: This application constitutes the actual data provider for new emergencies until more automated concepts are available. Intended for dispatchers only, this web application provides the possibility to manually initiate a new case by providing general information on an ongoing emergency and the corresponding unique location, as pair of latitude and longitude. In order to supply a user friendly interface, the location itself is automatically calculated as an approximation for a given address. This component demonstrates the first approach towards supplying the actual notification system with case data and is implemented as a JavaScript application embedded within a servlet..

3) Server-side applications: This component bundles the server-side functionalities of tracking and localizing the volunteers. Furthermore, the Case-Initializer is part of this component in order to provide fastest response times when invoking new emergency events.

4) Backend: The Backend represents the interface for persisting data and provides functions to enable communication between the database and other system components. Moreover, to ensure a consistent data usage within the system, all referenced data models and structures are defined within this component.

5) Webservices: Combining the REST based Web API, Websockets and client specific push technologies like Google Cloud Messaging, this component actually represents an intermediate communication layer; providing predefined functions for external modules and other clients to exchange data with the server.

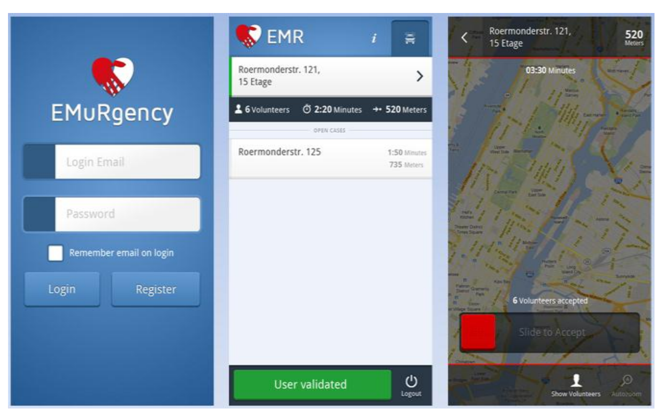

Figure 2: The mobile client application (android version)

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IV. Conclusion and Outlook

During the project, sociological and technical aspects are being combined. Country-specific differences in a variety of discussed parameters have been balanced against each other and are being implemented into an integrated VNS platform. Many fundamental difficulties were identified within the past sections of this paper whereas an advanced prototype of the software is available already - Fig. 2 shows screenshots of the android client application. While this prototype implements the essential components introduced in chapter three and enables base notification functionality for nearby volunteers, there are several potentially valuable features being discussed within the project at the moment.

A. *Potential future features*

The integration of chat channel functionality, enabling direct communication between the dispatcher and all volunteers who accepted a specific case, is one reasonable feature. By using the discussed advantages of a platform independent WebSocket connection, dispatchers will be able to exchange information with volunteers in real-time. Furthermore, status updates and newly received case details can instantly be broadcasted to all relevant receivers.

Another feature is the integration of existing applications or services that provide information on nearby automated external defibrillators (AEDs). Although the time critical aspect of CPR is the main concern for the first volunteer who arrives on scene, it can prove useful for further helpers, to have reliable information on nearby AEDs devices.

There are multiple scenarios in which the use of game design elements (gamification) within a VNS can be used to influence the user behavior; the adoption of a score system for attended courses or participated cases is one example. The general idea of gamification elements is to increase the user acceptance and motivation, whereas a sensible consideration is needed in order not to distract attention from the main topic.

Since modern smartphones and many other portable devices offer build-in functionality for photos and videos, a real-time media streaming from the place of incident is another possible feature with high benefit. The integration of telemedical concepts becomes possible and thereby enables an approach of professional helpers using their expertise to analyze the streamed data, in order to aid the volunteers at the scene with valuable information.

B. *Specification of a VNS and future development*

Within this paper, the basic concept of a VNS has been described and both essential and optional components have been discussed. Since many parameters are not yet fully determined and legal issues are still being discussed, there is no formal specification of a VNS at this stage of development. Diverse legal aspects still need to be cleared and options for integrating the system into the professional EMS workflow are being negotiated. Maintaining a highly agile programming approach will assure a continuous development and a fast integration of subsystems, adjustments and new requirements.

The research focus for the upcoming two years will be the development and implementation of new concepts to enable a generic integration of heterogeneous environments and devices. Architectural cloud approaches will be analyzed and tested, while the integration of the different partners and their corresponding research topics will form into a complex VNS platform.

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